NASA Contractor Report 165656

Analysis of GOES Imagery and Digitized Data for the SEV-UPS Period, August 1979

Clinton J. Bowley
Hsiao-hua K. Burke
James C. Barnes

ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
696 Virginia Road
Concord, Massachusetts 01742

CONTRACT NAS1-16108
FEBRUARY 1981

NASA
National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

NASA Contractor Report 165656

Analysis of GOES Imagery and Digitized Data for the SEV-UPS Period, August 1979

Clinton J. Bowley
Hsiao-hua K. Burke
James C. Barnes

ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
696 Virginia Road
Concord, Massachusetts 01742

CONTRACT NAS1-16108
FEBRUARY 1981

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

N81-16514#

FOREWORD

This study was performed by Environmental Research & Technology, Inc. (ERT) for the National Aeronautics and Space Administration, Langley Research Center (NASA/LaRC) under Contract No. NAS1-16108. The authors wish to thank Mr. Wendell G. Ayers and Mr. George L. Maddrea, Jr., of the Environmental Field Measurements Branch, Marine and Applications Technology Division, for their assistance throughout the contract period.

Because of the loss of contrast in the reproduction process, the GOES images (Appendices A and B) are not reproduced as part of the report but are on file at NASA Langley Research Center, in Hampton, Virginia. Those wishing to review these images may contact Mr. Maddrea, at the Langley Research Center, Hampton, Virginia 23665, or phone him at Area Code 804/827-2486.

This Page Intentionally Left Blank

TABLE OF CONTENTS

This Page Intentionally Left Blank

LIST OF FIGURES

1. INTRODUCTION

1.1 Purpose and Objectives

The Southeastern Virginia Urban Plume Study (SEV-UPS) is a program to address air quality problems and scientific understanding of the production of secondary pollutants in the troposphere downwind of urban complexes with remote sensing technology. As part of the study, an experiment using aircraft remote sensing techniques was conducted in the Norfolk, Virginia urban area during August 1979. In support of that experiment, data from the GOES satellite were collected and analyzed for the month of August. The purpose of the GOES data analysis was to provide a detailed summary of the synoptic meteorological conditions for use in the evaluation of air quality data collected during the month-long period of the SEV-UPS experiment.

The objectives of the study of GOES data were as follows: (1) collect GOES sectorized images covering the eastern United States (from approximately North Carolina to New England and west to the Mississippi River) for up to three observation times each day of the period; (2) perform an analysis of the imagery based on the observed cloud patterns and other weather data, indicating on clear overlays features such as low pressure centers, fronts and squall lines, surface and upper level wind flow patterns, and fog/haze areas; (3) prepare an overall summary of the synoptic conditions for the entire month of August; (4) review the GOES imagery to determine whether any regional haze patterns associated with elevated pollution episodes can be detected; and (5) if a haze pattern is apparent at some time during the sample period, analyze the extent and density of the haze using GOES digitized data.

With regard to the latter two objectives, a regional haze pattern was detected in the GOES images during the period of 6-11 August; ground-based aerosol measurements indicated a moderately high pollution episode did cover a portion of the eastern United States during that period. Digitized GOES data were acquired on magnetic tape from NASA/Langley Research Center for one observation time on each day of the 6-11 August period; in addition to analysis of the digital brightness levels, a model simulation of the total aerosol content was also performed.

1.2 Review of Previous Studies

In a recent study to evaluate the capabilities of satellite imagery for monitoring regional air pollution episodes, satellite data were compared with ground-based aerosol measurements from an extensive regional network (Barnes et al., 1979). The satellite data used in the study were from the NOAA/VHRR (Very High Resolution Radiometer), GOES (Geosynchronous Operational Environmental Satellite), and Landsat. The ground-based data were obtained from the SURE (Sulfate Regional Experiment), a comprehensive measurement program undertaken in 1977 because sulfates had been found to be a major component of the particles in the regional hazes that occasionally occur over the northeastern United States (Mueller et al., 1979).

In the study by Barnes et al. (1979), data were analyzed for three cases, each of which represented a significant pollution episode based on low surface visibility and high sulfate levels. The results of the analysis showed that when a regional air pollution episode has built up over a period of three to five days to a point where sulfate levels of $\geq 30\ \mu g/m^3$ are being measured, a haze pattern that correlates closely with the area of reported low surface visibilities ($\leq$ four miles) and high sulfate levels can be detected in satellite visible-channel imagery. The extent and transport of the haze pattern could be monitored from the satellite data over the period of the maximum intensity of the episode. In other cases, with lower levels of sulfate being measured, the haze patterns were more difficult to detect in the imagery. The results of the analysis were also evaluated in terms of the spatial and temporal measurement requirements of remote sensors for monitoring regional air pollution episodes; these measurement requirements are discussed in a separate report (Burke et al., 1979).

As part of these investigations, a limited sample of NOAA/VHRR digitized data was also analyzed, and a computer program was developed to simulate various atmospheric conditions, including normal clear conditions as well as conditions with clouds or pollution layers. The program, which can be applied to both the visible and infrared spectral ranges, consists of an atmospheric transmittance model and a radiative transfer model with the capability of performing multiple scattering

computations. The advantages of the model are that: (1) it is fast and requires little computational time to achieve satisfactory accuracy; and (2) it allows vertical inhomogeneity and the inclusion of surface effects. Estimates of aerosol loading derived from the model agreed quite well with the VHRR digitized reflectance values and surface aerosol and visibility measurements; the model, thus, proved to be a promising technique for assessing the capabilities of satellites to monitor pollution episodes.

The analysis of imagery from the various satellite systems indicated that in terms of orbital characteristics and areal coverage, the GOES geostationary system has the greatest potential application for monitoring pollution episodes on a regional scale. The principal advantage of a GOES satellite is its capability to provide more frequent observations (every half hour), which increases the probability for acquiring a cloud-free observation, and enables a region to be viewed at varying sun angles. GOES also has the capability to provide information on diurnal variations of pollutant episodes. For regional monitoring, the spatial resolution of the existing GOES visible channel sensor proved to be adequate.

1.3 Report Contents

The analysis of the GOES imagery is discussed in Section 2, together with the descriptive summary of the synoptic weather conditions for the month. The processing and analysis of the GOES digitized data for the period during which the regional haze pattern was evident in the imagery are discussed in Section 3. The results of the model simulation, including comparison with the digitized GOES data, are given in Section 4, and the conclusions are presented in Section 5.

Appendices A and B contain the analyzed GOES images. Because of the loss of contrast in the reproduction process, however, the GOES images (Appendics A and B) are not reproduced as part of the report but are on file at NASA Langley Research Center. Those wishing to review these images may contact NASA at the address given in the Foreword.

2. ANALYSIS OF GOES IMAGERY

2.1 Analysis Procedure

The GOES (Geostationary Operational Environmental Satellite) system provides satellite data on a routine basis. These data can be used together with standard surface and upper air observations as an input to synoptic analysis over land areas; over ocean areas, GOES often provides the only source of data for meteorological analysis. Since 1974, two GOES satellites have been stationed over the equator in earth synchronous orbits in positions to view the eastern and western United States. Because of their earth synchronous orbits, these satellites provide coverage of the earth's disc on an essentially continuous basis, with data being collected every one-half hour. The GOES sensor system is the VISSR (Visible Infrared Spin-Scan Radiometer), a two-channel radiometer. The visible channel operates in the 0.55 to 0.70 μm wavelength at a maximum spatial resolution of 1 km; the infrared channel operates in the 10.5 to 12.5 μm wavelength at a resolution of 7 km. The visible channel data can be processed at different resolutions depending on the size of the area viewed.

Two GOES images per day viewing the eastern half of the United States were acquired from the NOAA Satellite Data Services Division (SDSD) for the entire month of August 1979. These were the 2 km sectorized, visible images for 1500 GMT (1000 EST) and the infrared images for 1900 GMT (1400 EST). The analysis was carried out primarily using the 1500 GMT visible images. The infrared images were examined each day to assess whether any significant changes had occurred in the cloud patterns during the four-hour interval and whether any additional cloud information could be derived from the infrared cloud-top temperatures, particularly with regard to the development of afternoon convective cloudiness. It became apparent, however, that the infrared images did not offer much additional information, due in part, perhaps, to their poorer resolution. The analysis was concentrated, therefore, on the visible-channel imagery.

The analysis of the synoptic weather patterns on the entire GOES visible data set was completed utilizing both the 1200 GMT and 1800 GMT National Weather Service surface facsimile charts. The synoptic features

analyzed on clear acetate overlays included the locations of low pressure centers, fronts, squall lines, haze and fog areas, and the surface and 700 mb wind flow patterns. Large, open arrows were used to indicate surface wind flow regimes, while the 700 mb winds were plotted for each of the upper level reporting stations.

The GOES images with the overlays are included as an appendix to this report. The satellite images provide a more detailed indication of the cloud distribution on each day than can be derived from the surface and upper air reports alone. The images also provide an indication of the synoptic pattern off the coast to the east of the SEV-UPS area, where other data are lacking.

2.2 Descriptive Summary of Synoptic Weather Patterns for the Eastern United States During August 1979, Derived from GOES Images and Standard Meteorological Charts

A weak cold front moved slowly eastward across the Ohio Valley and mid-Atlantic states on 2 and 3 August, becoming nearly stationary along the coastal region on 4 and 5 August. The western extent of the Bermuda High which was located over the extreme southeastern states early in this period, expanded northward behind the front on 4 August, and hot, humid tropical maritime air dominated much of the eastern half of the United States until 12 August.

During the period from 4 to 12 August, daytime maximum temperatures ranged from about 30° to 35°C (86° to 95°F) throughout the eastern half of the U.S., while dew point temperatures ranged from the low to mid 20°C (67° to 76°F). Surface winds were generally light and variable throughout the region until 7 August, as the surface pressure gradient was extremely weak. On 7 August, winds became generally light southerly as far north as Ohio and Pennsylvania as the surface pressure gradient increased somewhat.

The analysis of late morning visibility isopleths, derived from the National Weather Service (NWS) hourly weather data for the period of 5 to 11 August, showed broad areas of the eastern U.S. experiencing visibilities of less than four miles in haze, with a number of isolated smaller areas of two miles or less visibility in haze.

By 12 August, a large anticyclone (high pressure system) had

advanced southeastward across the Great Lakes region and cooler dryer air extended all the way from eastern Canada, southwestward across the Ohio Valley into Oklahoma and Texas. A frontal system extended northeastward across Georgia, the Carolinas, and off the Virginia coast to just south of Cape Cod, and light rain fell in a narrow band along coastal sections from Virginia northeastward as far as Nova Scotia. The hot, humid, tropical air and accompanying pollution haze was now located well off the coast to the east of the frontal system.

The high pressure ridge moved eastward off the coast late on 14 August as a cold front in advance of another large anticylcone moved rapidly southeastward across the Ohio Valley region. On 15 August, the cold front extended from the Cape Hatteras region westward across Tennessee and Arkansas into Oklahoma, with cool dry air to the north, and warm, humid, tropical air to the south. High temperatures on this day generally ranged from 16°C to 19°C to the north of the cold front, and from 30°C to 33°C to the south of the front.

The center of this second anticyclone advanced southeastward across the Great Lakes during 16 August, and was centered over the mid-Atlantic coastal region late on 17 August. As surface wind flow became southerly behind the high pressure system on 18 August, warm, humid, tropical air moved northward across the eastern half of the U.S., with considerable haze being reported across the southern Gulf states into Tennessee and Kentucky, and light rainfall was reported over much of the northeast out ahead of a warm front located over western New York state and Pennsylvania. By 19 August, haze was being reported over much of the eastern half of the U.S., as far north as New York and southern New England. A weak frontal system pushed southward across Virginia, Kentucky, and into southern Illinois on 20 August, restricting the haze to the region of the Carolinas, Tennessee, Georgia and Alabama through 21 August. By 22 August, haze was only reported over North Carolina and southern Virginia out ahead of an approaching warm front. High pressure was centered over New England on this date, so that the haze was associated with a light easterly surface flow off the water.

With high pressure centers building east of New England and east of Florida on 23 August, and a low pressure disturbance moving northeastward across the Great Lakes region, surface winds gradually shifted into

a southerly flow across the eastern third of the U.S., with a small pocket of haze still present over Virginia and the Carolinas.

The low pressure disturbance was centered just south of James Bay on 24 August, and a trailing cold front extended southward across the eastern Great Lakes and Ohio Valley into western Tennessee, with the warm front extending southeastward across New York and Pennsylvania to off the mid-Atlantic coast. Winds were light southerly within the warm sector covering the eastern third of the U.S., and a band of showers were reported out ahead of the cold front in the Ohio Valley region extending southward to the eastern Gulf coast. No haze was reported on this day.

The cold front became stationary over the eastern coastal states on 25 August, and eventually weakened and dissipated by 27 August as the western extent of the Bermuda High advanced westward over the eastern third of the country. This westward expansion of the Bermuda High continued until the end of the month, with light southerly surface wind flow affecting the entire eastern half of the United States by 29 and 30 August.

3. ANALYSIS OF DIGITIZED GOES DATA FOR PERIOD OF ELEVATED POLLUTION EPISODE

3.1 Selection of Pollution Episode (from imagery analysis)

One of the objectives of the study was to determine whether a regional haze pattern associated with an elevated pollution episode could be detected in the GOES images. Although the overall synoptic weather pattern during August was not conducive to the development of a severe pollution episode, such as the July 1978 episode analyzed in the earlier study (Barnes et al., 1979), the synoptic weather charts described in the previous section did indicate several areas where reduced visibilities in haze were reported. The haze reports were the most widespread during the period of 6-11 August.

The initial GOES data set revealed little indication of the haze patterns reported on the six-hourly surface weather charts for the 6-11 August period. In order to determine whether the difficulty in detecting any haze patterns might be due to the low contrast of the matte photoprints, a request was made to have the 1500 GMT visible images reprocessed at a higher contrast. Examination of these reprocessed 2 km sectorized GOES images showed that the widespread haze patterns, which extended across the middle Atlantic and southeastern states into the Tennessee-Alabama region, were considerably more apparent than in the initial data set. This was particularly true of the haze patterns extending well off the east coast over the darker background of the cloud-free ocean areas. The reprocessed GOES images for 6-11 August are also included in the appendix.

To provide a further assessment of the haze patterns, TIROS-N visible satellite imagery for the same period were also acquired for comparison with the GOES data. A review of these data showed, however, that the haze patterns were not as evident in the TIROS-N images as in the GOES 2 km sectorized images. The difference was primarily the result of the approximately 4½ hour later time frame (1930 GMT) of the TIROS-N orbital crossing over the area of interest. By the mid-afternoon (local time), considerable low level cumuliform cloudiness had developed across the haze region obscuring much of the haze evident earlier in the day; some dissipation of the haze may also have occurred by mid-afternoon.

The haze patterns detectable in the GOES images correspond closely with the areas of low visibility (2 to 4 miles) reported in the surface observations. Moreover, surface-based aerosol measurements from reporting sites in the TVA and SURE networks indicate higher sulfate levels during the 6-11 August period, with some values exceeding 30 $\mu g/m^3$. Therefore, although the pollution levels were not as high as those measured in some episodes, such as during July 1978, the haze patterns were considered to be sufficiently distinct, so that the period was selected as an episode of air pollution with regional haze clearly identifiable in the satellite imagery. For this period, GOES digitized tape data were acquired from NASA/LaRC. The data on file at LaRC were averaged to 8 km resolution, but were deemed adequate for study of the reflectance values over the relatively broad haze regions.

3.2 Processing and Analysis of GOES Digitized Data

The output of visible data from the GOES VISSR sensor system is digitized on-board the satellite and transmitted in real-time to earth. The quantization of the visible data is 6 bits such that the data ranges between 1 and 64 digital counts, with higher numbers representing brighter intensities.

The field-of-view of the VISSR sensor system provides a nominal ground resolution of approximately 1 km. It provides eight parallel west-east visible data lines per west-east scan, covering the 8 km north-south band scanned by each step of the scanning mirror. The digital data obtained from NASA/LaRC, however, was already reduced to the 8 km band; therefore, each pixel of the digital data provided to ERT was of the size of 8 km resolution.

The episode of 6-11 August 1979 was considered the best case to perform the digital data analysis. The procedure for data analysis was different from the previous studies (Barnes et al., 1979; Burke et al., 1979) in that the data were processed for the entire region of interest instead of for selected scan lines only. The analysis was also extended to include the ocean in order to understand both the transport of the haze and also its characteristics over an ocean background.

After preliminary analysis of the data, it was decided that in order to evaluate a regional haze pattern, further reduction in the

scale of the digital printouts would be necessary. Therefore, a further averaging (1 to 4) of the data was carried out, and the tapes were processed for the southeastern part of the country and the coastal Atlantic ocean region for the entire six-day (6-11 August 1979) period.

A portion of the processed data for the Tennessee Valley area and southeastern states on 9 August is shown in Figure 3-1. Cloud areas can be identified because they have brightness values of 25 or greater, whereas the normal background has a typical value of 17 or less. Comparison with the visibility and surface-based aerosol measurements indicates that brightness values of 18-19 are representative of moderate haze conditions, and brightness values of 20 or greater with more severe haze conditions, such as seen in the Tennessee Valley area.

3.3 Comparison Between GOES Digitized and Imagery Data

The GOES digitized data were plotted on the same base map as was used for the analysis of the imagery. The areal averages are presented for each of the six days in Figures 3-2 to 3-7. Over land, normal (haze free) conditions were present in the northern part of the U.S. and Canada. Haze-free conditions were also observed in southern areas on most days and along the Atlantic coast on 11 August. Brightness values of 18-19 are typical of moderate haze areas. Over the ocean, the transport of the haze pattern is also apparent. Brightness values of less than 12 were representative of clear conditions. Brightness values up to 16 represented moderate haze conditions, whereas values of 17-18 were typical of more pronounced haze patterns.

Haze patterns also were easily recognizable in the Gulf Stream area. On 11 August, for example, clear conditions were evident in the Atlantic Ocean area immediately off the coast, but there was a distinct haze pattern further to the east. This haze pattern was a few hundred kilometers wide and was surrounded by clear conditions both on the east and west sides.

In summary, the analysis of the digitized data indicates that cloud and clear (haze-free) areas can be easily distinguished both over land and over ocean. Moreover, haze patterns are also well defined in the maps plotted from the averaged digitized reflectance values. It appears, therefore, that the digital data presentation is superior to the imagery, where contrast is sometimes not significant enough to define the haze pattern.

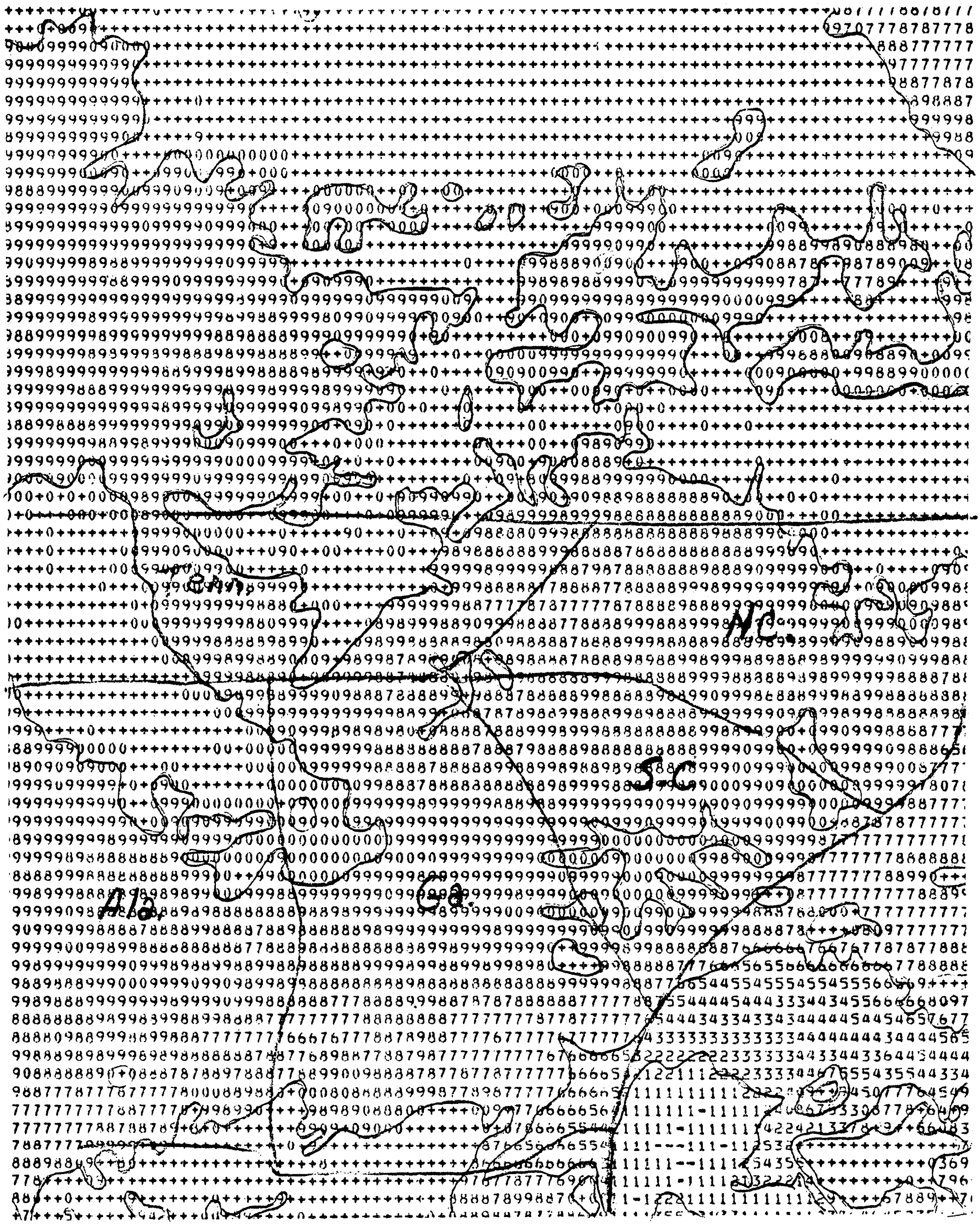

Figure 3-1 A portion of the digital printout of 9 August 1979, showing the Tennessee Valley area and southeastern United States. The approximate state boundaries are indicated. The brightness values represented by a single digit are as follows; the plus (+) symbol represents a value of greater than 20 counts, zero represents 20, 9 equals 19, 8 equals 18, etc. The minus (-) symbol represents a brightness value of 10 or less.

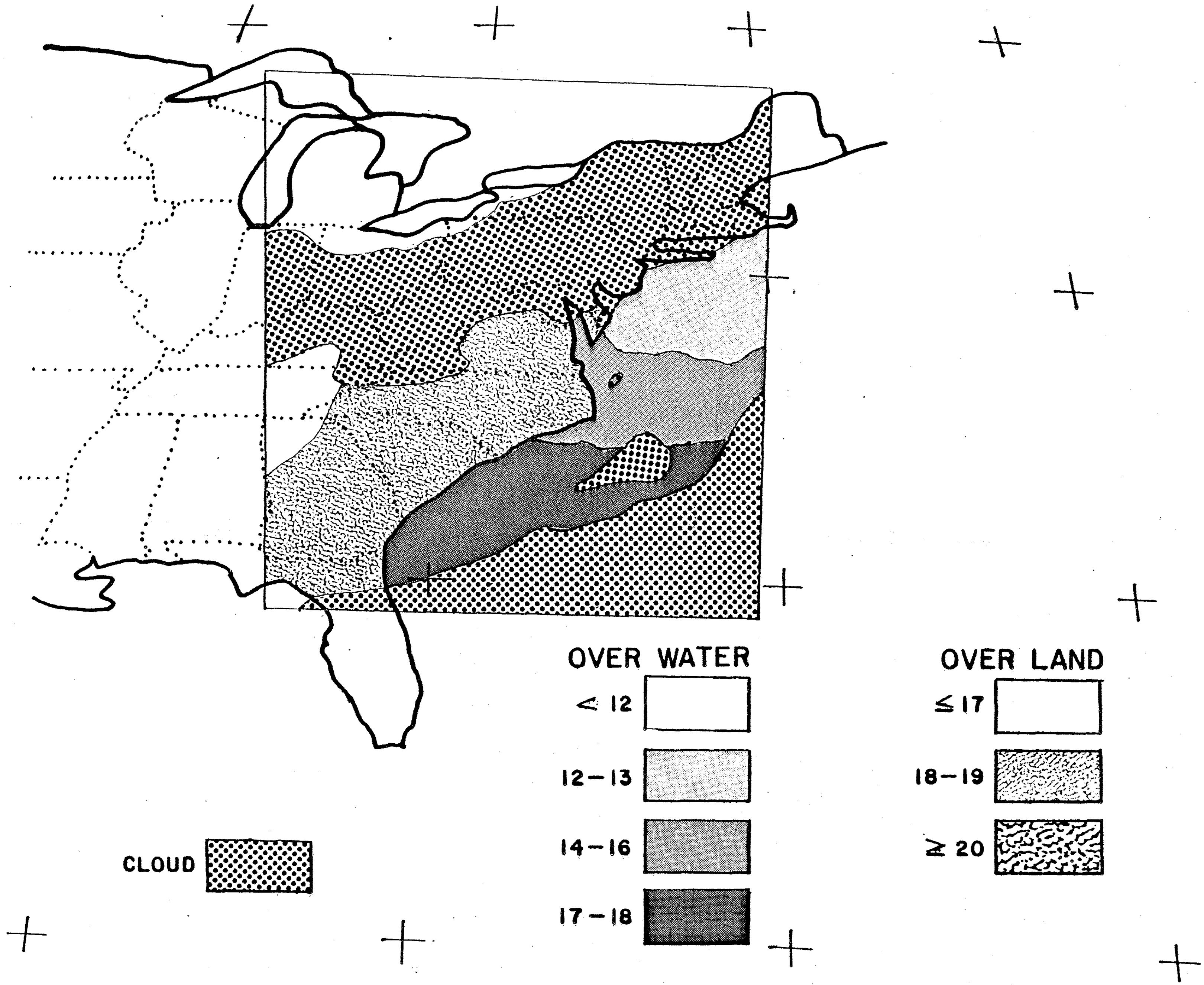

Figure 3-2 Map showing areal averages of digitial brightness values for 6 August 1979.

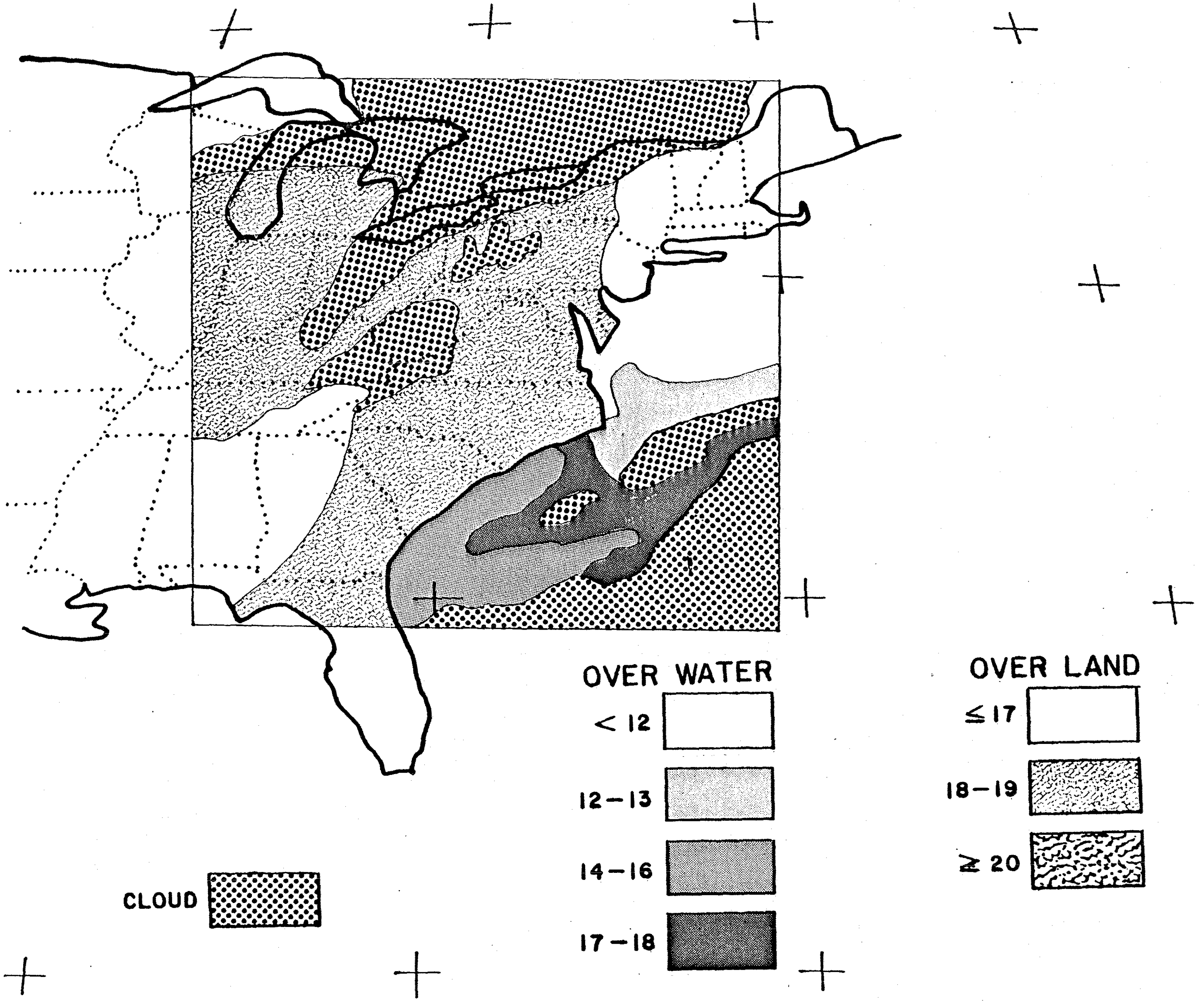

Figure 3-3 Map showing areal averages of digital brightness values for 7 August 1979.

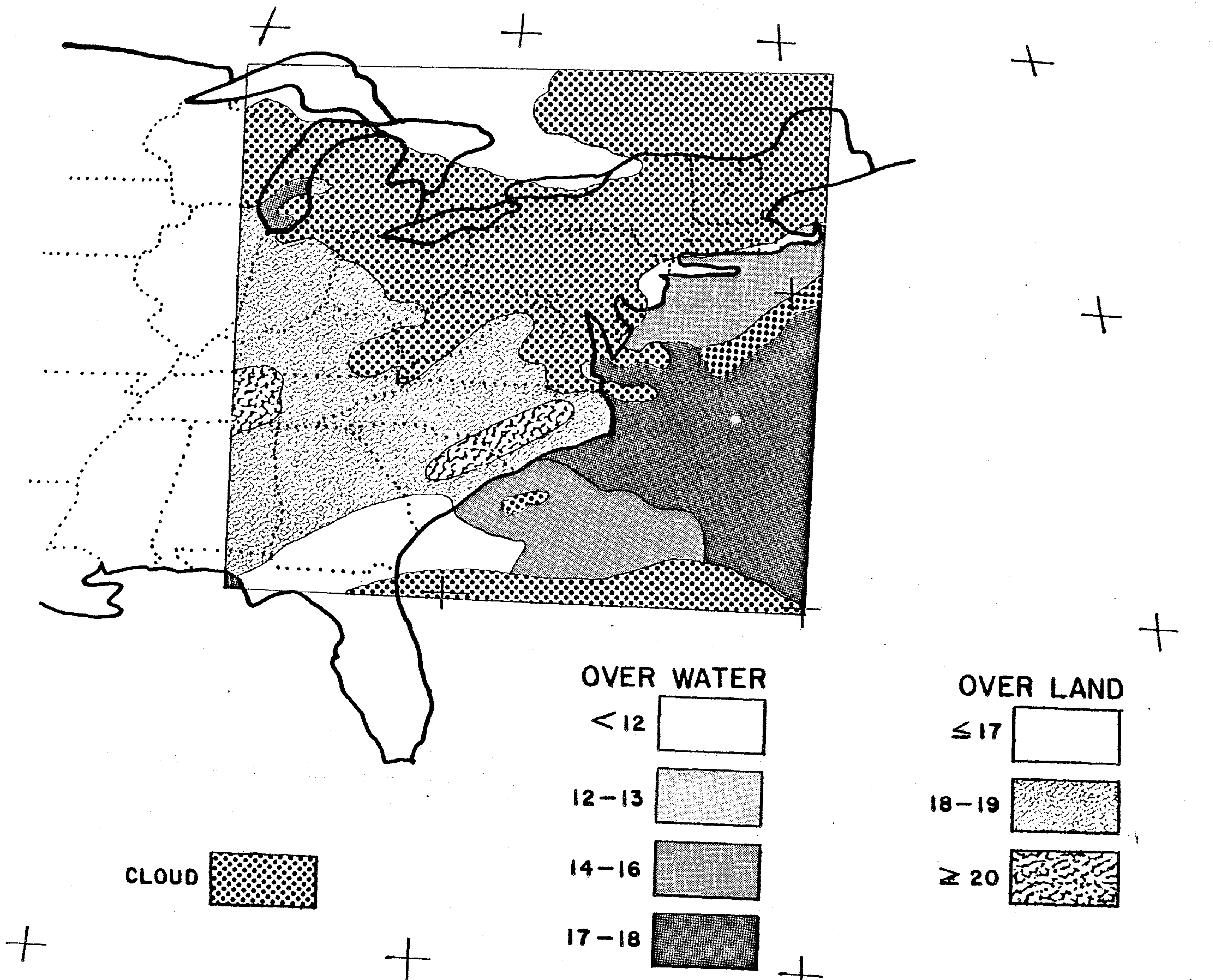

Figure 3-4 Map showing areal averages of digital brightness values for 8 August 1979.

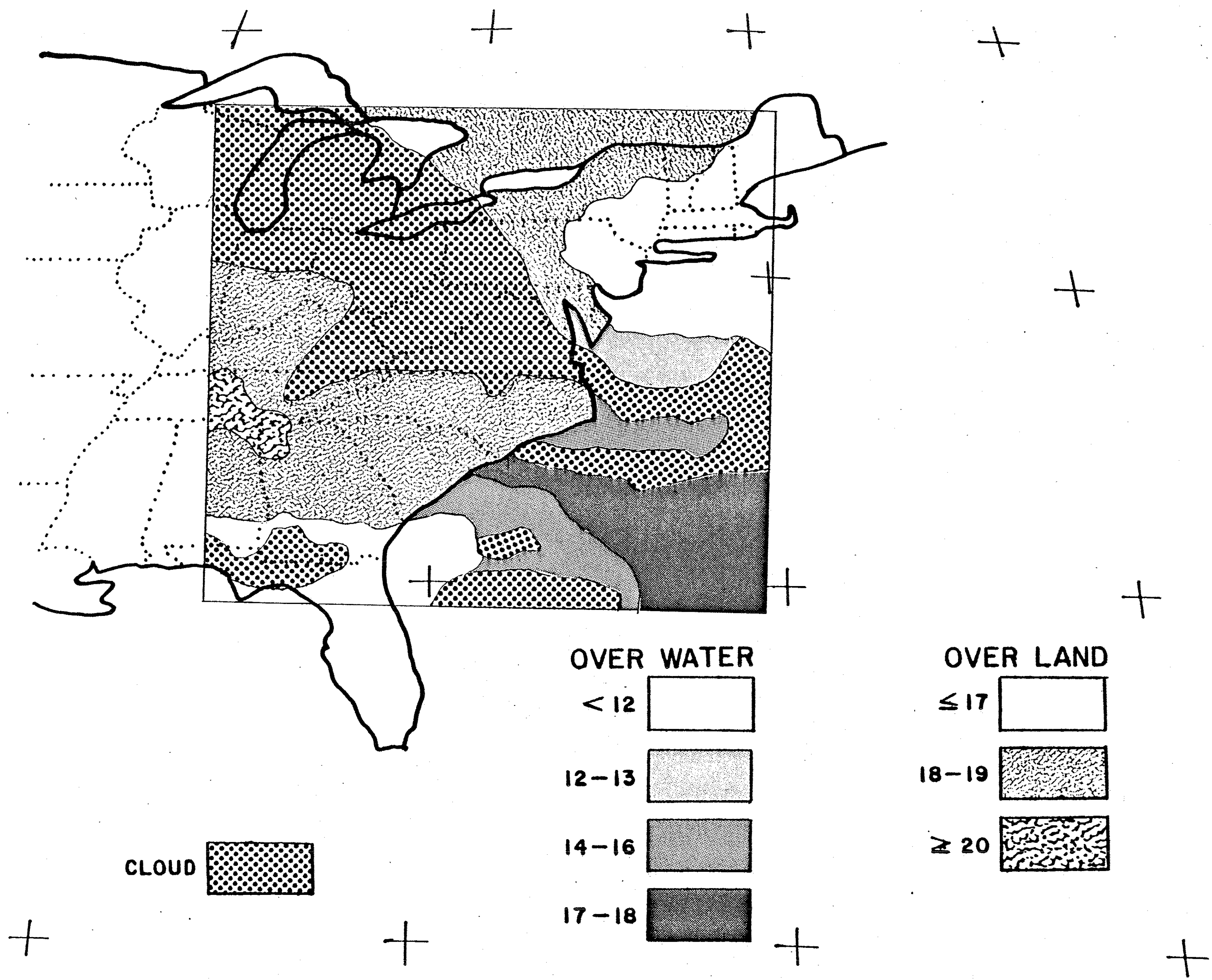

Figure 3-5 Map showing areal averages of digital brightness values for 9 August 1979.

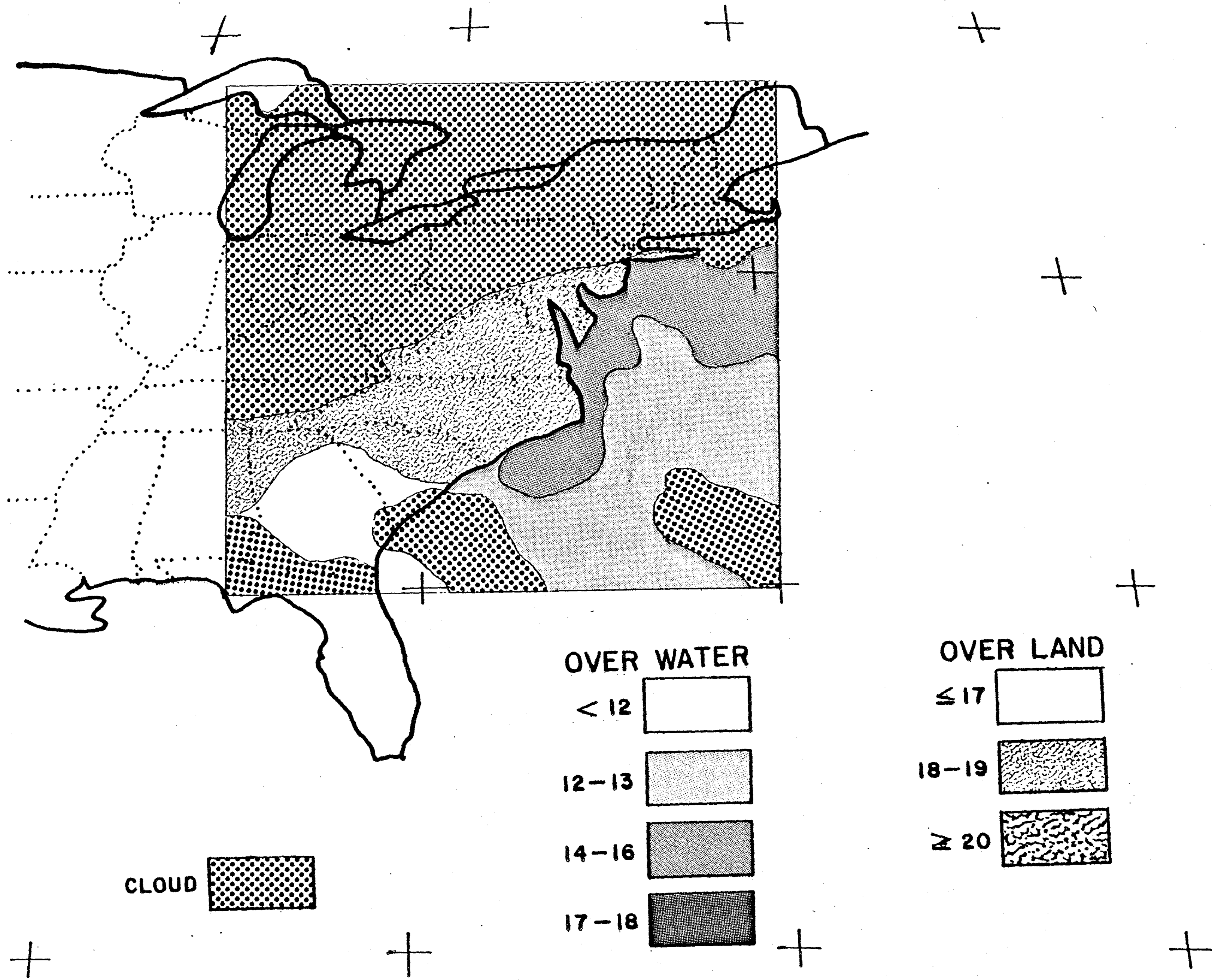

Figure 3-6 Map showing areal averages of digital brightness values for 10 August 1979.

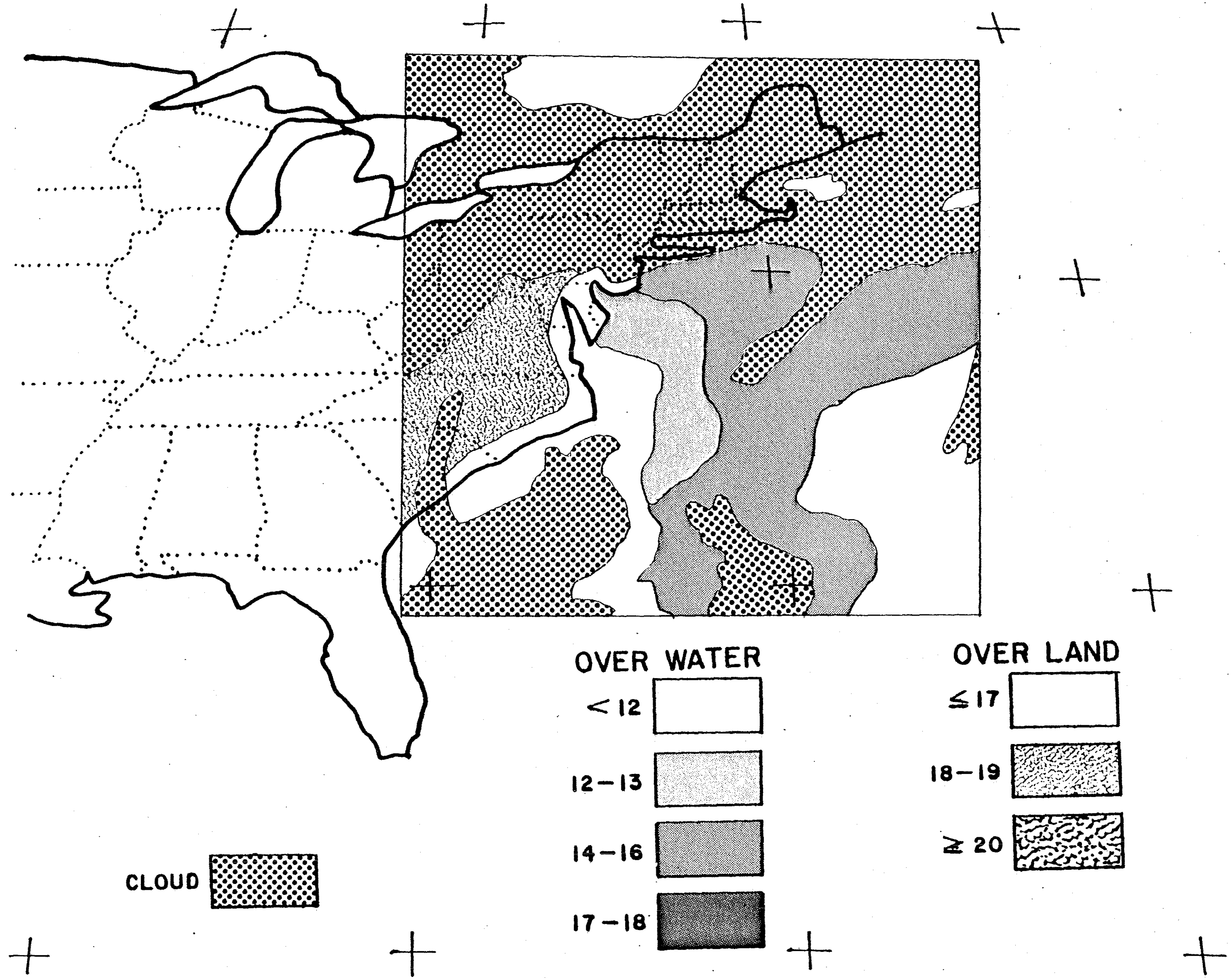

Figure 3-7 Map showing areal averages of digital brightness values for 11 August 1979.

4. MODEL SIMULATION OF AREAL AEROSOL CONTENT

4.1 Review of Modeling Technique

The modeling approach for inferring aerosol loading of a haze pattern has been described in detail in previous reports (Barnes et al., 1979; Burke et al., 1979). In summary, the absorption coefficients of aerosol particles in the visible spectral range, are always much smaller than the scattering coefficients, such that the single scattering albedo is always close to 1. Moreover, the scattering-to-mass ratio maximizes at a particle radius of about 0.3 μm, indicating that particles in the size range of a few tenths of microns are much more effective light scatterers than either larger or smaller particles. Although sulfate particles contribute only part of the total mass of pollutants, they dominate the optical properties (the light scattering effect) over other pollutants because their size range is generally a few tenths of microns, which is the range of the most effective light scatterers. Because of this feature, it is feasible to detect and monitor pollution episodes with high sulfate concentrations from a space-borne sensor.

In addition to sulfates, concentrations of other particulates also have to be taken into consideration for radiative transfer model computations. These other optical contributors include other particulates and nitrogen dioxide. Defining the concentration and the size distribution of various pollutants is a complex task, however, as it depends upon wind speeds, relative humidity, mixing heights, and other meteorological conditions; the approach described in the previous reports, therefore, models the various pollutants using the Labadie plume size distribution. In this approach, it is necessary to assume corresponding particulate concentration values in addition to those of sulfates, since fixed values of other particulates independent of sulfate concentration are not realistic. Generally speaking, although concentrations of sulfate and total particulates are not directly related, there is a tendency for higher concentrations of total particulates with increasing sulfate concentrations. This effect is adopted for pairing the sulfate and particulate concentrations.

Another parameter to be defined is the mixing height of the pollution

layer. The mixing height is determined from various meteorological conditions, and for surface pollutants is generally of the order of 1500 m; this value was used for the model computations in this study. In addition to the mixing height, the surface reflectivity is yet another variable to be determined. The surface reflectivity varies with the wavelength of the sensor, as well as with surface conditions. The effect of surface reflectivity is discussed in more detail in Section 4.2. The procedure of model computation can be summarized as follows:

1) select an atmospheric model including prescribed temperature, humidity and gas constitutent profiles, background visibility and surface reflectivity;

2) define the solar angle and the satellite view angle;

3) compute the atmospheric opacity and single scattering profiles at defined wavelength;

4) perform the radiative transfer compilation for intensity observed from satellite;

5) introduce additional amount of sulfate and particulates representative of the regional concentrations and define the mixing height;

6) repeat 3 and 4 to obtain the new intensity and thus the brightness contrast; and

7) repeat 5 and 6 for different concentrations.

The computer program developed in the previous studies referenced above, consists of an atmospheric transmittance model and a radiative transfer model with the capability of performing multiple scattering computation in a fast and accurate fashion. The results of model computations as applied to this study are summarized in the next section.

4.2 Comparison of Model Results with GOES Digitized Data

The model analysis performed under Task 5 of the present study was extended to include an ocean background to demonstrate that the technique can be applied to various surfaces with different reflectivities.

Figure 4-1 shows the average surface reflectivity for a range of surface types. The GOES visible sensor is most sensitive to a wavelength of about 0.6 μm. At this wavelength, reflectivity of non-snow land surfaces is typically 0.1. This value was used in previous studies and proved to be sufficiently accurate. Over water, the surface reflectivity is around 0.05.

Model computations were carried out using these surface reflectivity values of 0.1 and 0.05, respectively. The computed ratios of satellite observed intensity against normal background condition for various sulfate concentrations are shown in Figure 4-2. The normal background is assumed to be an atmosphere with sulfate concentration of 10 $\mu g/m^3$, consistent with the U.S. Northeast summertime averages. It is also assumed in the computation that the solar angle and sensor look angle are near vertical.

As seen in Figure 4-2, the contrast for a sulfate concentration of 40 $\mu g/m^3$ is 1.3 times the normal background for a surface reflectivity of 0.1. For a surface reflectivity of 0.05, the contrast ratio is 1.6. In other words, for the same amount of aerosol loading the contrast against normal conditions is more enhanced over surfaces with lower reflectivities. The implication is that haze is more observable over a water surface than a land background. In Figure 4-3, the relative intensity (brightness) seen through a normal atmosphere for a range of surface reflectivities (0 - 0.2) is plotted. The relative intensity is normalized to one for a surface reflectivity of 0.1. As can be seen, the intensity for a surface reflectivity of 0.05 is only 0.64 of that over a surface with a reflectivity of 0.1. The ratio over a surface with a reflectivity of 0.15 is 1.65.

It is obvious that the observed intensities are strongly related to surface reflectivities. The optimal approach for interpreting observed intensities (brightness) is to (1) define average surface reflectivity according to general surface types, (2) establish "base values" from observing the number of intensity or brightness counts under normal (cloud free and haze free) conditions, (3) compute the ratio of observed intensity to the base value, and (4) infer the aerosol loading from the computed intensity ratio.

The results of computation of the predicted number of "counts" for

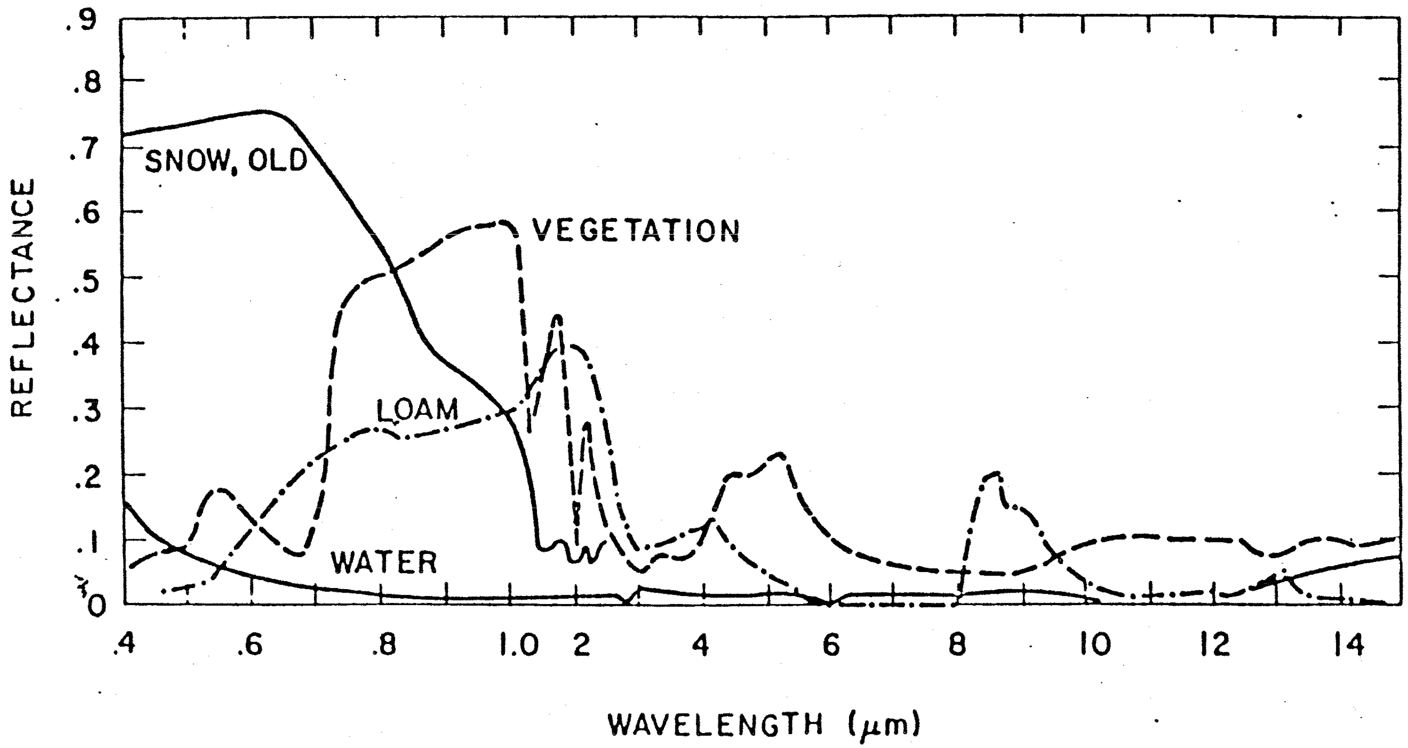

Figure 4-1 Typical surface reflectance of water, snow, dry soil and vegetation (after McClatchey et al., 1972).

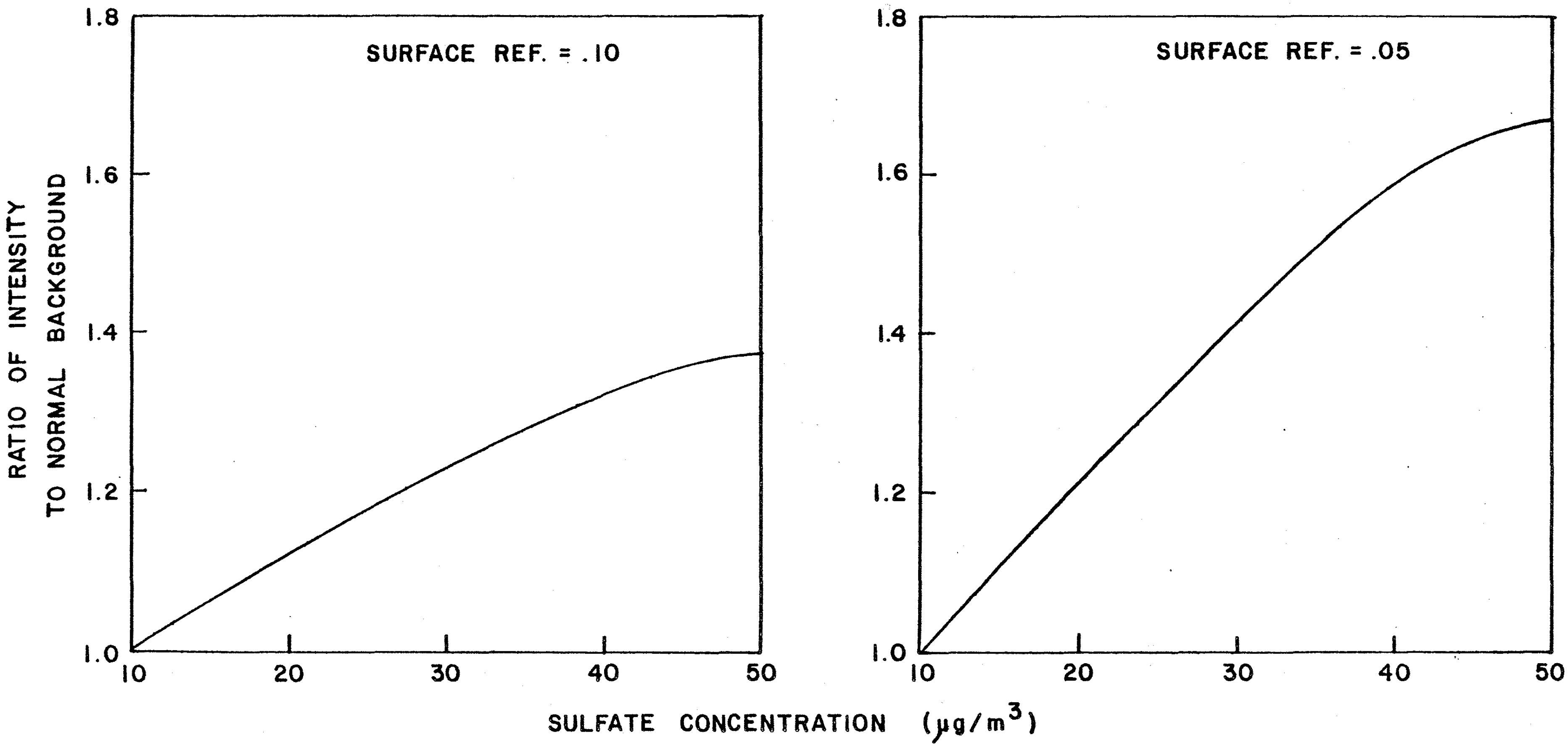

Figure 4-2 Ratio of brightness intensity in the visible range as viewed from space compared to normal atmosphere case for various sulfate concentrations (assuming sulfate concentration of 10 $\mu g/m^3$ as normal background value).

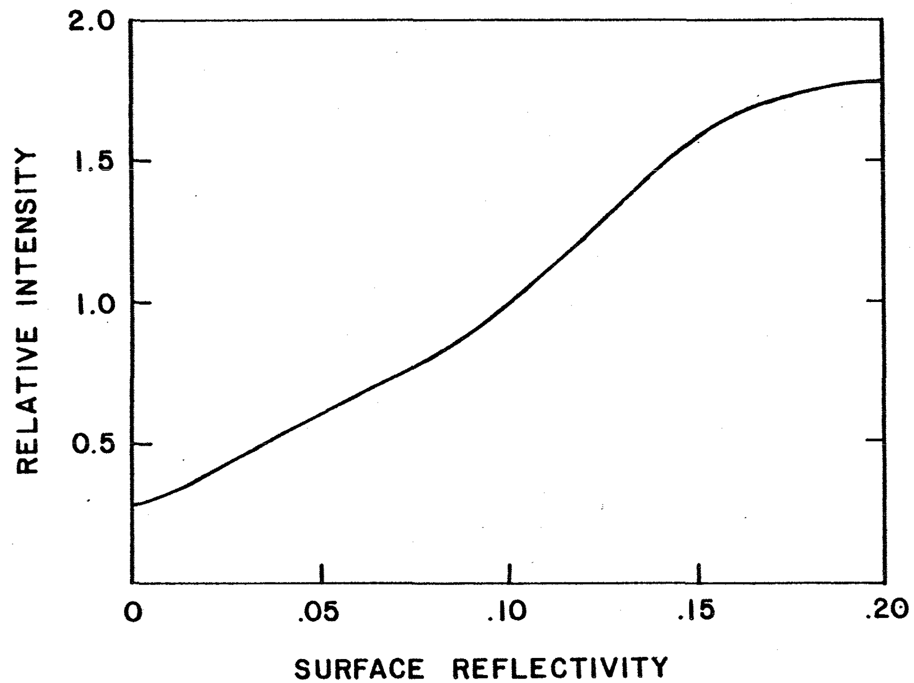

Figure 4-3 Relative intensities in the visible range as viewed from space for various surface reflectivities through normal background atmosphere.

the GOES visible sensor for various sulfate concentrations is shown in Figure 4-4. The counts under normal conditions for ocean and land surfaces are ≤ 12 and ≤ 17 respectively. This is consistent with the assumption of .05 and .1 surface reflectivities. For a haze with sulfate content of approximately 25 $\mu g/m^3$, the counts over ocean and land are in the ranges of 14-15 and 18-19, respectively. For a high concentration, up to 40 $\mu g/m^3$, the counts are approximately 18 over ocean and 20 over land.

These inferred values are quite consistent with the maps of GOES digital counts presented in Section 3.3. Of particular interest are the higher intensities (≥ 20) observed in the Tennessee Valley areas on both 9 and 10 August; these higher counts are consistent with the elevated sulfate levels measured on those dates (TVA and SURE data), and the lower visibilities reported.

Over the ocean, distinct patterns are also observed. The transport of the haze pattern can be easily defined. Despite the lack of sufficient surface truth measurements over the ocean areas, the observed intensity pattern is consistent with what had previously been observed over land.

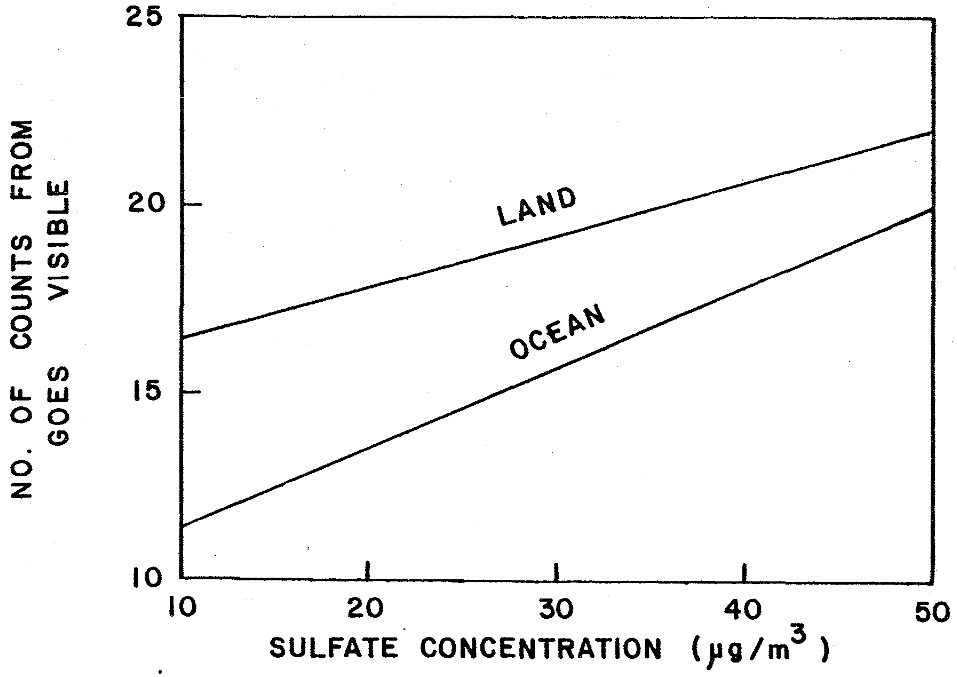

Figure 4-4 Predicted number of brightness counts from GOES visible sensor as a function of sulfate concentration over land and ocean.

5. CONCLUSIONS

The purpose of the study was to analyze GOES imagery together with standard meteorological data for August 1979 and, if a regional haze pattern was clearly detectable in the imagery, to acquire and analyze GOES digitized data for the period of the haze episode. The analyzed GOES images provide an additional source of meteorological input useful in the evaluation of air quality data collected during the month-long period of the SEV-UPS experiment. Furthermore, a clearly defined regional haze pattern was evident in the GOES images during the period of 6-11 August; an analysis of digitized data was, therefore, carried out for this period.

Analysis of the imagery indicates that even though the GOES visible channel data are not as sensitive as the data from the current NOAA satellites, regional haze patterns are, nevertheless, clearly detectable in the images. Moreover, the observed haze patterns correspond closely with areas indicated in surface-based measurements to have reduced visibilities and elevated pollution levels. When using GOES imagery, however, the photographic processing can be important with regard to haze detection; the regional haze patterns were much better defined in reprocessed, higher-contrast images than in the original photoprints.

Because of potential variations in photoprocessing, the GOES digital data presentation appears to be superior to the imagery for haze detection. Even using reduced-resolution averaged data, the results of the analysis indicate that digitial reflectance counts can be directly related to haze intensity. For the period of the elevated pollution episode, clear, haze-free land areas had reflectances generally ≤ 17 counts, whereas cloud reflectances were ≥ 25 counts. Counts of 18-19 were consistently observed in areas of moderate haze, and counts of ≥ 20 were observed in areas of more intense haze, where surface-based measurements of sulfate levels generally exceeded 30 $\mu g/m^3$. Over the ocean, the normal background was generally <12 counts, whereas moderate hazes were observed to have up to 16 counts, and the more intense hazes consistently 17-18 counts.

A model simulation of areal aerosol content indicates that atmospheric haze is more observable over backgrounds of low reflectance

(water) than higher reflectance (land). The observed intensities, therefore, are strongly related to the surface reflectivies. The model results agree closely with the observed GOES digital reflectance counts, providing further indication that satellite remote sensing can be a useful tool for monitoring regional elevated pollution episodes.

6. REFERENCES

Barnes, J.C. C.J. Bowley and H.K. Burke, 1979: Evaluation of the Capabilities of Satellite Imagery for Monitoring Regional Air Pollution Episodes (NASA Contractor Report 159107), Final Report under Contract No. NAS1-15307 for NASA Langley Research Center, Environmental Research & Technology, Inc., Concord, Mass.

Burke, H.K., C.J. Bowley and J.C. Barnes, 1979: Evaluation of the Spatial and Temporal Measurement Requirements of Remote Sensing for Monitoring Regional Air Pollution Episodes (NASA Contractor Report 159092), Final Report under Contract No. NAS1-15531 for NASA Langley Research Center, Environmental Research & Technology, Inc., Concord, Mass.

McClatchey, R.A., R.W. Fenn, J.E.A. Selby, F.E. Volz and J.S. Garin, 1972: Optical Properties of the Atmosphere - 3rd Edition, AFCRL-72-0497.

Mueller, P.K. et al., 1979: The Occurrence of Atmospheric Aerosols in the Northeastern United States, paper presented at the Conference of Aerosols: Anthropogenic and Natural Sources and Transport, New York Academy of Sciences, New York, NY.

APPENDIX A

ANALYZED GOES VISIBLE IMAGES: 1-31 AUGUST 1979

APPENDIX B

REPROCESSED GOES VISIBLE IMAGES: 6-11 AUGUST 1979

The GOES images are on file at NASA Langley Research Center. Those wishing to review these images should contact NASA at the address given in the Foreword.

1 Report No NASA CR-165656	2 Government Accession No.	3. Recipient's Catalog No
4 Title and Subtitle Analysis of GOES Imagery and Digitized Data for the SEV-UPS Period, August 1979		5 Report Date February 1981 6 Performing Organization Code
7 Author(s) C.J. Bowley, H.K. Burke and J.C. Barnes		8 Performing Organization Report No A533F 10 Work Unit No
9 Performing Organization Name and Address Environmental Research & Technology, Inc. 696 Virginia Road Concord, Massachusetts 01742		11 Contract or Grant No NAS1-16108 13 Type of Report and Period Covered Contractor Report
12 Sponsoring Agency Name and Address National Aeronautics & Space Administration Washington, D.C. 20546		14 Sponsoring Agency Code

15 Supplementary Notes

NASA/Langley Research Center Technical Monitor: G.L. Maddrea, Jr.

Final Report

16 Abstract

In support of the Southeastern Virginia Urban Plume Study (SEV-UPS), GOES satellite imagery was analyzed for the month of August 1979. The analyzed GOES images provide an additional source of meteorological input useful in the evaluation of air quality data collected during the month-long period of the SEV-UPS experiment. In addition to the imagery analysis, GOES digitized data were analyzed for the period of 6-11 August, a period during which a regional haze pattern was detectable in the imagery.

The results of the study indicate that the observed haze patterns correspond closely with areas shown in surface-based measurements to have reduced visibilities and elevated pollution levels. Moreover, the results of the analysis of digitized data indicate that digital reflectance counts can be directly related to haze intensity both over land and ocean. The model results agree closely with the observed GOES digital reflectance counts, providing further indication that satellite remote sensing can be a useful tool for monitoring regional elevated pollution episodes.

17 Key Words (Suggested by Author(s)) satellite data analysis GOES imagery SEV-UPS data period	18 Distribution Statement Unclassified - Unlimited

19 Security Classif (of this report)	20 Security Classif (of this page)	21 No of Pages	22 Price*
Unclassified	Unclassified	29	

N-305

For sale by the National Technical Information Service, Springfield, Virginia 22161

End of Document